Evidence-based Field Research on Health Benefits of Urban Green Area

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과학적 근거를 바탕으로 한 도시녹지의 건강편익에 관한 연구

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국문초록

건강과 삶의 질 향상에 대한 관심이 커짐에 따라 도시녹지가 가져다 주는 건강편익이 크게 주목되고 있지만, 이에 관한 객관적이고 과학적인 데이터는 매우 부족한 실정이다. 따라서 본 연구에서는 도시녹지가 가져다 주는 건강편익에 대한 과학적 자료를 얻기 위해 생리적, 심리적 지표를 활용하여 실험을 실시하였다. 과거병력이 없는 20대 남자 대학생 20명이 실험에 참가하였고, 자극은 녹지와 도시에서 실제의 경관을 15분간 감상하는 것으로 하였다. 이번 연구는 충남대학교 의학전문대학원 생명윤리심사위원회의 승인을 받은 후 실시되었다. 녹지와 도시에 대한 생리반응을 분석한 결과, 도시에 비해 녹지에서 심박동수가 현저히 감소하였고, 안정상태에서 증가하는 부교감신경활동이 유의하게 향상되었으며, 스트레스호르몬의 일종인 코티솔 농도가 낮아지는 경향이 보였다. 심리반응에 있어서는 부정적인 감정과 정신상태가 녹지에서 보다 유의하게 낮아진 반면, 활력은 유의하게 증가하였다. 이번 연구의 결과는, 녹지를 접하는 것이 심리적 변화뿐만 아니라 인체의 자율신경계와 내분비계 활동에 긍정적 변화를 가져다 준다는 것을 보여주는 것으로써, 녹지가 도시민의 건강증진과 관련하여 매우 직접적인 환경요인이 될 수 있음을 과학적으로 뒷받침한다고 할 수 있다.

주제어: 녹지경관, 건강증진, 심박동변이, 타액코티솔, 심리적 안정

ABSTRACT

With increasing interest in health promotion and quality of life, growing attention has been focused on the beneficial effects of urban green area. However, very few evidence-based approaches have been conducted on the health-related benefits of urban greenery. Therefore, this study examined the health-related benefits of green areas using physiological and

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psychological indices to obtain evidence-based data on these benefits. Twenty male university students were selected as subjects. Data were collected when participants viewed landscapes in a green area or an urban area for fifteen minutes. This research was reviewed and approved by the Ethics Committee of School of Medicine, Chungnam National University. Physiological data in the green area revealed significantly decreased heart rates, significantly increased high-frequency value of heart rate variability, an index of parasympathetic activity, and reduced salivary cortisol concentration, a stress hormone, compared to the urban area. Psychological tests showed the green area significantly reduced the negative mood state and psychological symptoms, and significantly increased the positive mood state. Our data provided evidence for the health-related benefits of green areas, and the findings of this study support that green areas can play a critical role in health promotion for urban residents, by positively affecting autonomic nervous and endocrinal activities.

Key Words: Green Landscape, Health Promotion, Heart Rate Variability, Salivary Cortisol, Psychological Relaxation

Ⅰ. INTRODUCTION

Growing attention has been focused on the beneficial effects of urban green area, with increasing reports supporting the theory that today's artificialized urban environments may have negative effect on individuals' and communities' health(IUHPE, 1999; Tzoulas *et al.*, 2007). Rising interest in health promotion and quality of life, especially in developed societies, is now fueling societal attention on the health-related benefits of green area.

To date, many studies have been conducted on the positive effects of green area on humans and it is already well known that greenery helps improve emotional states(Ulrich, 1979), recovering attentional fatigue(Herzog *et al.*, 1997; Kaplan and Kaplan, 1989; Hartig *et al.*, 1991), relieve stress(Ulrich *et al.*, 1991; Kaplan, 1995) and increase job satisfaction(Leather *et al.*, 1998; Shin, 2007). Additionally, recent demographic research supports positive relationships between urban green area and the perceived general health of residents(Maas *et al.*, 2006), longevity in senior citizens(Takano *et al.*, 2002), and socioeconomic health(Mitchell and Popham, 2008). However, very little evidence-based approaches have been conducted on the health-related benefits of greenery(Yi, 2006; Lee *et al.*, 2011), despite numerous studies. Some studies have provided physiological data on the human response to nature-oriented stimulations(Yi, 2003; Suda *et al.*, 2007; Lee *et al.*, 2008; Park *et al.*, 2009a), but most of these experimental studies were conducted in controlled indoor rooms. Although indoor studies can be useful for exploring the effects of specific stimulation, it cannot fully reflect the therapeutic effects of real green environments. In fact, reliable scientific data on the health-related benefits of real green area are still lacking and very little has been known about the kind of therapeutic effects that can be obtained from contact with green area.

Many scientists have emphasized the importance of field research(Groenewegen *et al.*, 2006; Lee *et al.*, 2009; Miyazaki *et al.*, 2011), because field research can provide crucial data on human responses to real environments. In fact, the therapeutic effect of green area is obtained from overall stimuli through the five senses(Miyazaki *et al.*, 2011), meaning a field search is fundamental to verify the more direct health benefits of green area. In order to investigate human physiological activities in outdoor fields, stable physiological measurement technology is required. To date, although it has been considered very difficult to obtain reliable physiological data outdoors, the rapid progress in technologies measuring and analyzing physiological activities in recent years has spawned a new methodology for evidence-based field research(Miyazaki *et al.*, 2011). Moreover, some recent field research using this methodology has actually revealed interesting data concerning human physiological reactivity to real forest environments, including central nervous, autonomic nervous and endocrine activities(Park *et al.*, 2007, Park *et al.*, 2008, Lee *et al.*, 2009; Lee *et al.*, 2011). However, there remains a lack of evidence-based data on the health benefits of urban green areas, despite numerous studies showing the psychological benefits of urban greenery.

Therefore, the purpose of this study was to examine the health-related benefits of urban green areas through physiological and psychological indices and provide evidence-based data on these benefits.

Ⅱ. METHODS

1. Subjects

Twenty male university students were selected as subjects. Those who were habitual smokers or drinkers, and who had previous cardiovascular or mental disorders were excluded. Their mean age was 24.0(standard deviation=2.1). To increase the validity of the physiological data, the gender and age of the subjects were controlled. Before the experiment, the contents of the study were thoroughly explained and a written description was provided. All the subjects agreed to the study protocol and signed written informed consent. This research was reviewed and approved by the Ethics Committee of School of Medicine, Chungnam National University(CNU).

2. Field Sites

The field study was performed in October 2009. The field site selected for the experiment was a green area within the campus of Chungnam University(hereinafter referred to as green area; Figure 1). Nowadays, the university campus is used as a restorative green area, not only for university members but also for urban residents, as more and more universities are opening their campus to local societies. Given that the role of the university campus as an urban green area has become more prominent, the need has arisen to examine its health-related effects in an evidence-based way. As a control, an urbanized downtown area near Chungnam University was selected(hereinafter referred to as urban area).

3. Experimental Protocol

Twenty subjects were randomly divided into two groups of ten persons, and the experiment was conducted over two days. On the first day, the first randomly selected group performed the experiment in the green area, and at the same time, the other group did the same procedure in the urban area. On the second day, the two groups swapped over field sites with each other and performed the same experiment. Each subject viewed a real landscape of green or an urban area for fifteen minutes in a seated position. Heart rate and heart rate variability(HRV) data was collected continuously throughout the experiment and saliva was sampled after each fifteen-minute viewing. Psychological tests were also performed after viewing each landscape.

Figure 1. A participant viewing the landscape of green area(left) and urban commercial area(right) in a seated position.

4. Data Collection and Analysis

As for physiological indices, heart rates and heart rate variability(HRV) were measured as an index of autonomic nervous activity, and salivary cortisol concentration was investigated as an index of endocrine activity. Autonomic nervous activity consists of sympathetic and parasympathetic nervous activities, which are respectively antagonistic to each other. In general, sympathetic nervous activity is elevated when in a state of tension or stress, and conversely, parasympathetic nervous activity is increased when in a relaxed state(Sakakibara *et al*., 1994). Since sympathetic and parasympathetic nervous activities can be analyzed separately by measuring HRV, it is possible to determine whether the body is in a relaxed or stressed state. Heart rates and HRV data were collected using a potable electrocardiogram measurement instrument(Activtracer AC-301A, GMS, Japan). The heart rate was analyzed on the basis of one-minute segments by averaging out the R-R heart beat data. HRV data was analyzed by using the Maximum Entropy Method(MemCalc/win(GMS, Tokyo, Japan)). The data was interpreted and analyzed by dividing it into low-frequency elements(LF; 0.04-0.15Hz) and high-frequency elements(HF; 0.15-0.40Hz; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). HF was used as a marker of parasympathetic nervous system, and LF/(LF+HF) was used as a marker of sympathetic nervous system(Cacioppo *et al*., 1994; Weise and Heydenreich, 1989). In the HRV data, however, there were significant differences among individuals, so it was analyzed by converting it into natural logarithms. The data on the heat rates and HRV was finally analyzed for the 19 subjects, since there was an error for one subject when collecting the data.

Cortisol is one of the representative stress hormones secreted from the hypothalamic-pituitary-adrenal(HPA) axis. Salivary cortisol can be easily sampled noninvasively from the saliva, and has been verified as a useful biological marker to measure the degree of stress to which a body is subject(Kirschbaum and Hellhammer, 1994; Sluiter *et al*., 2000; Seplaki *et al*., 2004). Saliva was taken by using Salivette(No. 51.1534; Sarstedt, Numbrecht, Germany), and the saliva samples collected were kept frozen and analyzed in a laboratory.

Four different kinds of questionnaires were used to investigate the psychological responses, subjective impression evaluation by the semantic differential(SD; Osgood *et al*., 1957) method, profile of mood states(POMS; Mcnair and Lorr, 1964), state-trait anxiety inventory(STAI; Spielberger, 1983) and symptom check list-90-revision(SCL-90-R; Derogatis and Cleary, 1977). The questionnaire was filled in before and after viewing each real landscape. SD evaluation was performed by using three pairs of adjectives with seven scales, including 'comfortable-uncomfortable', 'soothed-aroused' and 'natural- artificial'. The POMS data was analyzed by dividing it into six subscales, including tension-anxiety(T-A), depression(D), anger-hostility (A-H), vigour(V), fatigue(F) and confusion(C), and the total mood disturbance(TMD) was calculated by subtracting a vigour(V) score out of the sum of the other five subscales. This indicates that the higher the TMD value, the stronger the subjects' negative emotions. In the POMS test, a shortened version with thirty questions was used to reduce the burden on the subjects. The SCL-90-R, a multidimensional psychological test instrument, was used to assess psychological symptoms and psychological distress. The SCL-90-R scores were calculated by dividing it into nine subscales, such as somatization(SOM), obsessive-compulsive(O-C), interpersonal sensitivity(I-S), depression(DEP), anxiety(ANX), hostility(HOS), phobic anxiety(PHOB), paranoid ideation(PAR) and psychoticism(PSY), respectively.

All the data was shown as mean±standard error(Mean±SE). A paired *t*-test was used to compare the differences in physiological reactivity between the green and urban areas. Also, a Wilcoxon signed rank test was applied to analyze the differences in psychological indices between the two environmental stimuli. The significant level was defined as $p<0.05$.

III. RESULTS

1. Differences in Physiological Reactions to the Green and Urban Areas

In the comparison of physiological indices between the green and urban area, key differences were observed. Heart rates during the fifteen-minute viewing of the real landscapes were found to have significantly decreased(2.81%) in the green area(83.1±0.6), compared to the urban area(85.5±0.6; $p<0.01$; Figure 2). When comparing the results of HRV data, a significant difference was found in ln(HF) between the two environmental stimuli, which is a marker of parasympathetic nervous activity. The green area(5.26±0.28) showed a 3.05% higher value than the urban area in ln(HF)(5.08±0.26; $p<0.01$; Figure 3). In the comparison of ln(LF/(LF+HF))

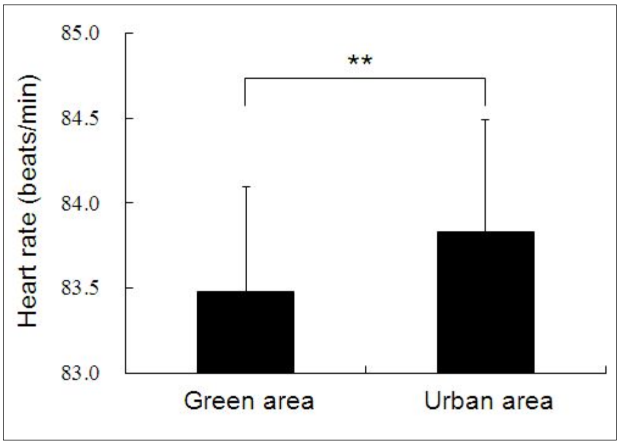

Figure 2. Comparison of heart rates between green and urban areas when viewing real landscapes for fifteen minutes. N=19; mean±standard error; **, $p<0.01$; Paired *t*-test.

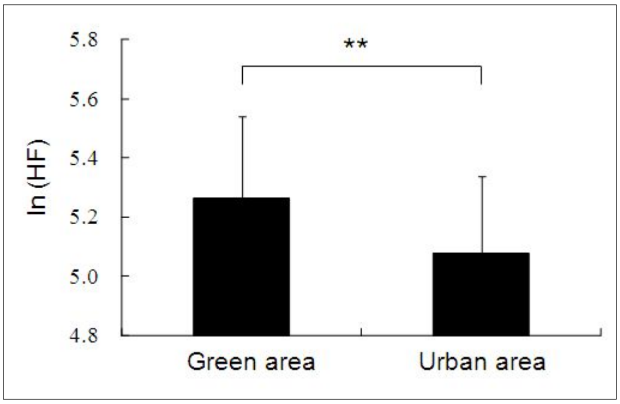

Figure 3. Comparison of ln(HF) values between green and urban areas when viewing real landscapes for fifteen minutes. ln(HF) indicates natural logarithm of high-frequency power in heart rate variability analysis. N=19; mean±standard error; **, $p<0.01$; Paired *t*-test.

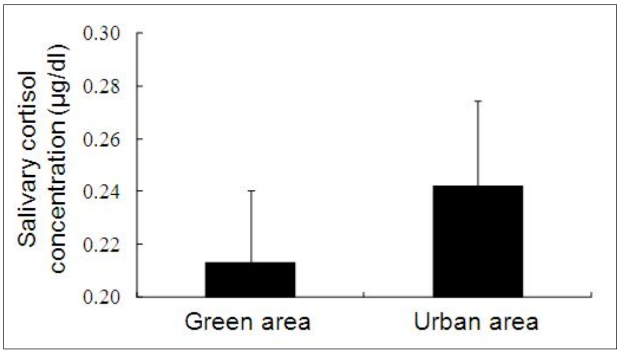

Figure 4. Comparison of salivary cortisol concentrations between green and urban areas after fifteen-minute viewing of real landscapes. N=20, mean±standard error, Paired t-test.

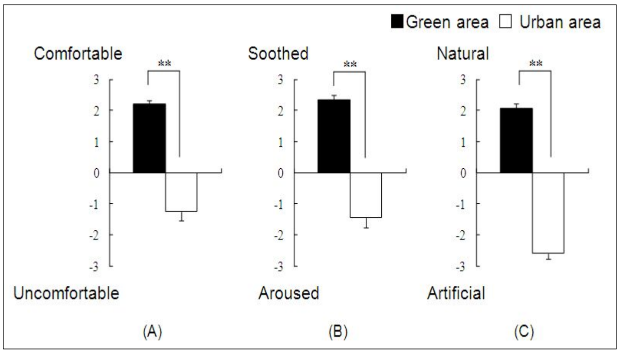

Figure 5. Subjective evaluation by semantic differential methods after fifteen-minute viewing of real green and urban areas using three pairs of adjectives, (A) comfortable-uncomfortable, (B) soothed-aroused and (C) natural-artificial. N=20, mean±standard error, **, $p<0.01$; Wilcoxon signed-rank test.

values, which is a marker of sympathetic nervous activity, no significant difference was detected between the two stimuli. In the analysis of salivary cortisol concentration, the green area tended to be lower than the urban area, but there was no significant difference between them(Figure 4).

2. Differences in Psychological Reactions to Green and Urban Areas

The results of the analysis of psychological responses to the real green and urban landscapes after the fifteen-minute viewing revealed notable differences between the two. Following the comparison of the SD scores, significantly higher scores were observed in the green area for three adjective pairs, 'comfortable-uncomfortable($p<0.01$)', 'soothed-aroused($p<0.01$)' and 'natural-artificial($p<0.01$)', compared to the urban area(Figure 5). Significant differences were also detected in the POMS test(Figure 6). The scores for negative subscales such as tension-anxiety(T-A; $p<0.01$), depression(D; $p<0.01$), anger-hostility(A-H; $p<0.01$), fatigue(F; $p<0.01$) and confusion(C; $p<0.01$), were found to have significantly decreased after viewing the green area, compared to the urban one. Conversely, positive mood states like vigour(V) were found to have significantly increased in the green area rather than the urban area($p<0.01$). In the comparison of total mood disturbance(TMD), the score for which increases with rising negative mood states, the score for thegreen area(−5.9±1.8) was found to be significantly lower than the urban area (15.1±4.2) after a fifteen-minute viewing of real landscapes ($p<0.01$). As a result of analyzing the STAI that investigates the degree of state anxiety, this was found to have decreased

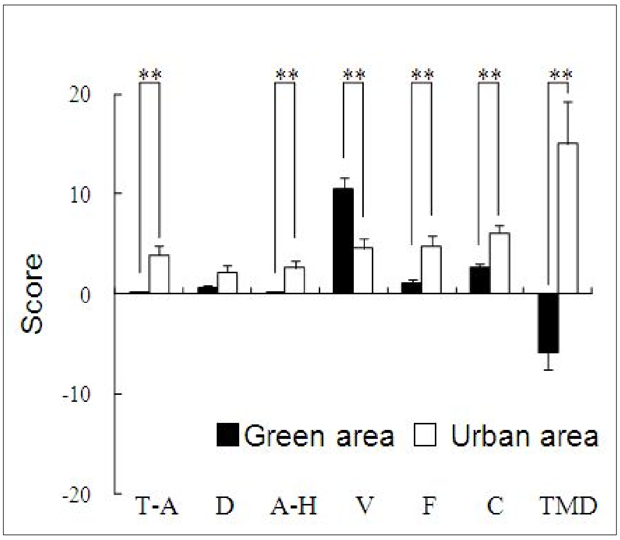

Figure 6. Comparison of the mood state after fifteen-minute viewing of real green and urban areas using shortened version of POMS. T-A, tension-anxiety; D, depression; A-H, anger-hostility; V, vigour; F, fatigue; C, confusion; TMD, total mood disturbance. N=20, mean±standard error, **, $p<0.01$; Wilcoxon signed-rank test.

by 40.6% in the green area(29.8±1.5), compared to the urban area(50.2±1.9; $p<0.01$; Figure 7). Likewise, in the analysis of SCL-90-R, the scores for the negative symptom subscales were found to have significantly decreased in the green area rather than the urban area, such as somatization(SOM; $p<0.01$), obsessive-compulsive(O-C; $p<0.01$), interpersonal sensitivity(I-S; $p<0.01$), depression(DEP; $p<0.01$), anxiety(ANX; $p<0.01$), hostility(HOS; $p<0.01$) and paranoid ideation(PAR; $p<0.01$), respectively(Figure 8).

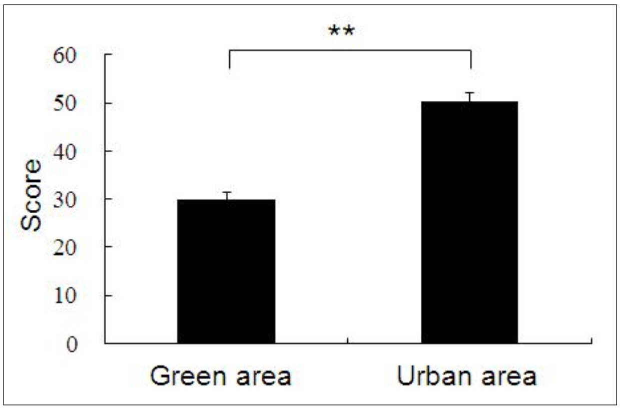

Figure 7. Comparison of the degrees of state-anxiety after fifteen-minute viewing of real green and urban areas. N=20, average±standard error, **, *p*<0.01; Wilcoxon signed-rank test

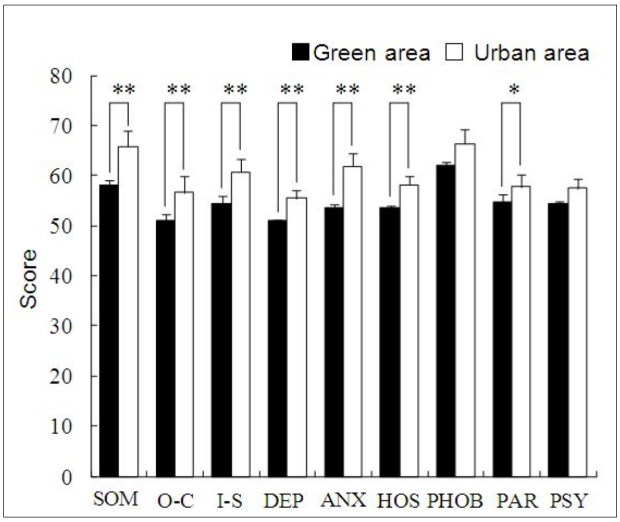

Figure 8. Score comparison of the subscales of the symptom check list(SCL-90-R) after fifteen-minute viewing of real green and urban areas. SOM, somatization; O-C, obsessive-compulsive; I-S, interpersonal sensitivity; DEP, depression; ANX, anxiety; HOS, hostility; PHOB, phobic anxiety; PAR, paranoid ideation; PSY, psychoticism. N=20, mean±standard error, *, *p*<0.05; **, *p*<0.01; Wilcoxon signed-rank test.

Ⅳ. DISCUSSION

Our result supported the theory that viewing real urban green area can benefit health by boosting physiological activity, as well as psychological states. Compared to viewing urban landscapes, the heart rates were found to have significantly decreased(2.81%), and analysis of HRV revealed elevated parasympathetic nervous activity in the green area(3.05%). Elevated parasympathetic nervous activity is often seen in the relaxation experience, including Zen meditation(Murata *et al.*, 2004) and soothing music(Iwanaga *et al.*, 2005). These data may support the theory that contact with real green area can boost the relaxation of autonomic nervous activity. In endocrine activity, the salivary cortisol concentration tends to decrease more in green areas rather than urban areas, which indicates that urban green areas can relieve physiological stress by acting directly on the endocrine system. These results on physiological reactivity partly correlate with those of previous studies whereby human physiological reactivity was investigated in relation to actual forest environments(Lee *et al.*, 2009; Park *et al.*, 2009b; Lee *et al.*, 2011), which may support the idea that the urban green area can have similar health benefits to those of natural forests. The fact that physiological activity was boosted by short-term contact with green area is crucial. The autonomic nervous system and the endocrine system play key roles in sustaining the homeostasis of the body. Given that recent adult diseases such as diabetes are closely related to autonomic dysfunctions(Nelson *et al.*, 2006), urban green area may play a greater role than expected in maintaining and promoting public health(Lee *et al.*, 2011).

In addition, our data supported the theory that urban green area can enhance psychological relaxation, as well as physiological merits. Based on the analysis of four psychological indices, subjects felt more comfortable, soothed, natural and vigorous when viewing the green landscape rather than the urban one. At the same time, the negative emotions and anxiety level were significantly reduced. These results on the psychological benefits of the green area are partly consistent with the previous findings(Ulrich, 1979; Hartig *et al.*, 1991; Kaplan, 1995). Our field data, however, may reflect the psychological effects of the urban green area more accurately than many other studies that were investigated indoors. Considering the increasing focus on mental health(Murray and Lopez, 1996), the psychological benefits of urban green areas should be reevaluated from the viewpoint of mental health promotion.

This study can be evaluated as very meaningful based on the perspective that it provided scientific evidence using biological markers to determine the physiological effect of actual urban green environments through field experiments. This study supports the theory that urban physical environments can affect human physiological activity more directly than expected and that constructed urban green areas like the university campus can also have health-related benefits. However, our results cannot be extrapolated to female and different age groups or ethnicities, because only twenty male adults participated as subjects. To generalize the findings, further evidence-based studies on a larger sample including various subject groups would be required.

Nowadays, natural environment has been recognized in many developed countries as an important factor for individual and community health and well-being, far beyond just an amenity(Lee *et al*., 2011). International research organizations, such as the International Union of Forest Research Organizations (IUFRO) and European Cooperation in Science and Technology (COST), have already launched and initiated new projects to utilize forests and urban green area to promote health. Henceforth, therefore, new approaches to urban landscape and green area are needed from a health promotion perspective, in cooperation with professionals in the areas of urban developing, landscape planning, regional planning, public health, and decision making. This field study may provide a key concept to open a new research area in the field of landscape architecture, promoting urban green area as a critical factor associated with health-related issues of urban residents. This research could be applied to the evaluation of therapeutic effects, the healing-space planning, park and urban planning for public health and so on.

In summary, our data provides the following evidence that contact with greens area has health benefits: (1) significantly lower values in pulse rate and negative psychological symptoms, (2) significantly higher values in ln(HF) of heart rate variability and a positive mood state, and (3) reduced salivary cortisol concentration, which is an index of stress response, in comparison with urbanized areas. Although these results can not be generalized due to the limitations in sample size and study sites, it is noteworthy that the health benefits of a green area were quantitatively measured using biological markers at field sites. These findings may open a new research area in the field of landscape architecture, promoting urban green area as a critical factor associated with health-related issues of urban residents.

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